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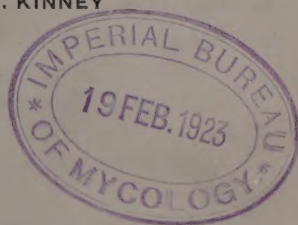
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The importance of the disease factor in tobacco production has been forced upon the attention of tobacco growers in the past two years by the widespread occurrence of the leaf spot diseases and the serious losses resulting from them. These diseases have caused considerable alarm to all tobacco growers because of the losses which they entail and also because of the fact that they can readily be recognized as diseases. Root-rot of tobacco is a much more serious disease, however, because it causes immense losses each year to a majority of Burley tobacco growers, and yet is recognized by comparatively few of them as a distinct disease. This disease rots the roots as they develop and, altho it does not kill the plant, stunts it seriously. In some cases it causes only minor losses due to late maturity and a slight decrease in the size of the leaf; in other cases the losses may be practically complete. It is common in the Burley section of Kentucky to see fields of tobacco in which the plants have made practically no growth thru the greater part of the summer but which, when a rainy season comes on, suddenly start into growth. Some of the plants may grow rapidly while others remain small and stunted. This condition is particularly common where tobacco is grown two or more years in succession and is especially marked when an abundance of barnyard manure has been added to the soil. These symptoms are commonly attributed to lack of rain, low soil fertility, or to tobacco being "hard" on the land. It has been determined definitely, however, that root-rot is the primary cause in most instances.

Fortunately, a method of controlling this serious disease has been found, which adds no burdens whatever to the already tedious task of growing the crop. It may actually cut down, to some extent, the labor involved in handling the crop in the field because of greater uniformity in growth of the plants (Figure 6.) This method is by the use of strains of tobacco resistant or immune to the disease. In the following pages will be given a discussion of the nature of tobacco root-rot and the progress which is being made in the development of resistant strains of Standup White Burley.

LOSSES CAUSED BY TOBACCO ROOT-ROT.

To any grower who has experienced the rapid decrease in yield on highly fertile soil where tobacco has been grown for two or more years in succession, or where tobacco has come fairly often in the rotation and has consistently produced low yields while other crops on the same land yielded well, it will not be necessary to point out the importance of controlling this disease. Some fields are not at all affected, while others may be a complete loss. Still others may appear on casual inspection to be doing well but on examination be found to have a considerable portion of the plants badly stunted and wilting during hot, dry periods. The fungus which causes root-rot is widespread in the tobacco growing sections of Kentucky. It has been found to be present in the majority of fields of White Burley examined during the past two years by the senior author. Undoubtedly some loss resulted in all of the infected fields even tho it may have been slight in some of them.

EFFECT OF ROOT-ROT ON CULTURAL PRACTISES.

The cultural practis common in the Bluegrass section of Kentucky of growing tobacco on bluegrass soil for one or two years and then seeding to bluegrass again for a long period of time is, in a large measure, due to the fact that the land becomes infected with the root-rot organism, thus making the growing of tobacco on the same land unprofitable until several years have past. Keeping the land in bluegrass decreases soil infection

after a few years to the point where it again becomes possible to raise a profitable crop of tobacco. The introduction of strains of Burley immune to the attacks of root-rot should make it possible to produce good yields in any system of cropping desired.

NATURE OF TOBACCO ROOT-ROT.

Cause. Root-rot is caused by a fungus* which lives in the soil for a long time after it has been introduced. It attacks the roots of tobacco, soon after the plants are set in the field, (Figure 2) causing them to rot and turn black (Figure 1). Because of this fact, the disease is known to many growers as black-root.



Figure 1. The root system of a plant of Halley White Burley (susceptible) and of one of the Judy's Pride White Burley resistant selections. Grown on diseased soil, 1920.

Plant-bed infection. Plant-bed infection may be expected where a plot of ground is used more than one season for the plant bed, unless the bed is steamed. Even plant beds on new ground may become infected by drainage from an old tobacco field. The plants in infected beds may appear entirely

**Thielavia basicola*.



Figure 2. The resistant selection P (left), Halley (center) and Q (right) showing the difference in early growth of resistant and susceptible strains when grown on diseased soil. 1920.

normal until about the time they are ready to be set. At this time the weather is likely to become warm and moisture deficient. Under these conditions the plants in the bed rapidly turn yellow and may even wilt in very hot weather. If such plants are pulled, the presence of root-rot can readily be seen. It is never safe to use plants from an infected bed.

Field Infection. Badly diseased plants will be found to have a mass of stubby black roots with only a few new white ones developing close to the surface of the ground (Figure 1). Because of this condition of the root system, diseased plants may wilt badly on hot days, reviving during rains or at night (Figures 3 and 6). It is not uncommon to see plants wilting again immediately after a considerable rain if the sun comes out hot. Plants only slightly infected may show no visible signs of the disease until the roots are closely examined. The loss may be quite considerable in such cases but not be apparent for lack of healthy plants for comparison. The extent of loss in such a field can be determined only by growing a row of resistant plants



Figure 3. Resistant selection Q (left), the susceptible variety, Halley (center) and resistant selection P (right). Selections Q and P were grown from seed of two of the original mother plants selected for resistance from the variety Judy's Pride. They illustrate two of the distinct types which are found in this variety and which breed fairly true to type. Selection P is typical of the 8 desirable selections obtained from the 16 original selections of Judy's Pride. Selection Q is the best of the twist-bud types obtained. The diseased Halley plants are wilting. Grown on diseased soil, 1920.

thru the field and observing closely the relative rates of growth thruout the season and obtaining relative yields. Many farmers in the Burley section who at present believe their fields to be disease-free would be greatly surprised at the results of such a test.

Relation of Degree of Infection to Root-rot. The extent of injury either in the plant bed or in the field depends directly on the amount of the fungus present in the soil. A few diseased plants one year may produce enough infective material in the soil to cause a complete failure the following year. It is because of this fact that an apparently disease-free crop of tobacco may be followed the next year by a complete loss due to root-rot.

Some growers have had success in setting plants from badly diseased beds in land free from the disease. In such cases the small amount of infective material is not sufficient to attack all the roots produced and as a consequence they are able to penetrate into disease-free soil and survive. The practice of setting diseased plants is very objectionable, however, as it may pollute a disease-free piece of land.

Altho it is true that root-rot usually appears only where tobacco has been grown, yet several instances have been observed in which land which had not been plowed for many years showed a high degree of infection. In these cases it was possible to trace the source of infection to drainage from an old tobacco field.

METHODS OF CONTROL.

The losses from root-rot may be reduced greatly, even where very susceptible strains of tobacco are grown, if certain cultural directions are followed. These consist in: (1) Proper selection of seed-bed site, choosing only land which can receive no drainage whatever from old tobacco fields. Such a site should be used only once, unless the bed is steamed each year instead of burned. If steaming can be practiced, it is desirable to select a permanent seed-bed site fence it and use it continuously for this purpose and no other. (2) Tobacco should not be grown on land more than one year if the land is to be kept comparatively free from the disease; and a fairly long rotation should be practiced. If the seed-bed and the rotation are given close attention, there should be comparatively slight loss from root rot. It is obvious that with the present system of cropping these recommendations can not always be followed as it is not always economical to break up bluegrass sod for a single crop when it is capable as far as fertility is concerned of growing two and often four crops of tobacco. The necessity for the use of immune strains of tobacco is thus apparent.

RESISTANT STRAINS OF WHITE BURLEY TOBACCO.

The value of resistant strains of tobacco in controlling root-rot has been demonstrated in the Burley section of Kentucky thru the efforts of the agents of the United States Department of Agriculture.* That the use of resistant strains has not become widespread is due to the fact that the strains of resistant tobacco used did not meet with favor among Burley tobacco growers. The impression has grown, as a consequence, that resistance and undesirable qualities in tobacco are associated. That this idea is incorrect and that strains of White Burley can be developed which are resistant to root-rot and of as high quality as the varieties generally grown has been shown by experiments during the past two years at the Kentucky Experiment Station.

METHODS OF DEVELOPING RESISTANT STRAINS.

The method used in developing strains resistant to root-rot is simple. It consists merely in finding a severely diseased field in which a few plants are developing normally altho surrounded by severely diseased plants. The seed heads of such plants are bagged in order to prevent crossing. The seed of each original mother plant is sown separately the following year, and the plants set in individual rows on land known to be diseased. Susceptible varieties are set along side so that comparisons can be made between the selections and the check rows, to determine relative resistance, and between the various selections, to determine those of highest quality. Only the most resistant selections of the highest quality are retained for further testing and continued selection. During the first season's trial in the diseased plot the most desirable plants are selected from the best strains and these bagged for seed.

In all, 25 resistant strains of White Burley tobacco have been tested. These are the result of 16 selections made by Mr. Roy Milton in a field of Judy's Pride White Burley, and 10 selections made by one of the writers in a small plot of Vimont Kelley White Burley which was badly diseased. The former have been tested at the Experiment Station over a period of two

* U. S. Dept. of Agr. Bul. No. 765.

years, in soil heavily infected with the root-rot organism, and have been tested in several parts of the Burley section the past season. Fifteen of the selections proved resistant. The latter 10 selections have been tested one year, in diseased soil, and all proved highly resistant. Besides these, about 50 other selections have been made from a standup tobacco grown on the Experiment Station farm for the past 8 or 9 years, called Station Kelley.



Figure 4. A typical plant of Judy's Pride White Burley, selection P. It is typical of the most desirable strains obtained from Judy's Pride White Burley. Grown on diseased soil, 1920.

JUDY'S PRIDE WHITE BURLEY SELECTIONS.

The results obtained from the 16 selections of Judy's Pride White Burley are interesting not only from the standpoint of the resistant strains obtained, but also because they show quite clearly that our so called varieties of White Burley tobacco are not varieties in the true sense of the word but are rather a mixture of strains (Figures 3 and 6).

From these 16 mother plants, 15 strains were obtained practically immune to root-rot, while one strain produced only a single moderately resistant plant. Ten of the resistant strains were of the desired standup type and were nearly uniform (Figure 4). Two were evidently hybrids as both broadleaf plants and twist-bud plants were obtained. Three strains were of the twist-bud type and nearly uniform (Figure 3). The breadth of the leaf varied slightly within a strain, but there were considerable differences in the breadth of leaf among the various strains. The uniformity of plant type within any one strain (with the two exceptions mentioned) was very marked (Figures 2 and 3). At stripping time considerable differences in color and quality were apparent between the strains. The twist-bud types produced the roughest, poorest colored leaf. Because of undesirable field characters and quality as shown at stripping time, 8 of the original 16 strains have been discarded.

Field Trials. Because of the marked uniformity in type and resistance shown by the most desirable strains in 1920, it was considered advisable to obtain information as to the value of these strains in comparison with the commonly grown varieties under field conditions. Therefore small lots of seed of the strains which were considered best in 1920 were sent out thru county agents or direct to a few growers to test in comparison with the commonly grown varieties. The results of these tests are very promising. Of 18 answers to requests for information, 14 men stated that the strains were better, and 4 said it was as good as their own variety. Of those who thought the resistant strains as good as their own, all four raised the crop on land not infected with root-rot. The growth was about the same in each of these cases as compared with the local variety and the

quality about the same. One of these men reported that the resistant strain was much more uniform than his own variety. The reasons given by the 14 men who considered the resistant



Figure 5. A single plant of Selection As. 9, a resistant selection of Vimont Kelley. It is typical of the ten selections made from this variety at Dry Ridge, Ky., in 1920. Grown on diseased soil, 1921. The method of bagging to prevent cross-pollination is shown.

strains better than their own, included earlier and more constant growth thruout the season, greater uniformity in growth and, without exception, earlier maturity. Earlier maturity results probably because the resistant plants can continue growth thru dry periods, as the root systems are not decreased by rot. Of those who expressed an opinion as to quality, 13 considered the quality of the resistant strains distinctly better than that of their own, and two stated they could see little difference. These results seem to show clearly that it is possible to develop strains of White Burley of high quality which are resistant to root-rot.

It certainly is possible to develop strains of White Burley which, because of uniformity, will give a crop of a higher average quality than that of the varieties commonly grown. This is true because the commonly grown Burley varieties are a mixture of strains. We have demonstrated that some of these strains are decidedly poorer in quality than others and when mixed with them, necessarily lower the average quality of the crop. The selection of a high-quality pure strain automatically eliminates the poorer strains and, as a consequence, raises the average quality of the crop. From the results obtained thus far, it would seem that our best resistant selections represent the better strains, as to quality, contained in the commonly grown varieties. As a consequence, it may be expected that a more general use of such strains will increase the average quality of the crop raised in the Burley section, both because of uniformity and earlier maturity.

VIMONT KELLEY SELECTIONS.

In 1920, one of the writers found a small garden plot set to Vimont Kelley White Burley tobacco at Dry Ridge, Kentucky. This plot of ground had been heavily manured the previous seasons, with the object of raising a large crop of tobacco on a small piece of land. The crop, with the exception of about 10 plants, scattered over the plot, and a few plants near the fence, was practically a failure. The small plants many of which were not over 3 or 4 inches high, were found to be badly diseased. An occasional plant within two feet of such stunted plants was normal

in development and just coming into flower. With the permission of the owner*, these plants were bagged to protect the flowers from being cross-pollinated. The seed of ten of these plants was sent to the Experiment Station in the fall. These strains have been tried the past season and without exception proved to be very resistant to root-rot. The ten strains were all very much alike as to quality, type and resistance. Within all the strains there was some variation indicating that improvement may still be made by selection. These strains produce a heavier, broader, longer leaf than the selections previously discust and have the leaves placed closer on the stalk. Further tests of them will be necessary before their true value can be ascertained.

STATION KELLEY WHITE BURLEY SELECTIONS.

In testing the various strains in diseased soil every 5th row was planted to a variety not considered to be resistant. In 1920 the White Burley variety Halley was used. This proved to be very susceptible and was therefore a good variety for this purpose, as marked contrasts were evident in the growth of it and in the growth made by the resistant selections (Figures 1, 2 and 3). In 1921, Station Kelley White Burley was used as the check. This is called Station Kelley because the seed has been saved annually from plants of Kelly's Improved Standing Up Burley variety grown on the Station farm for the past 8 or 9 years. It was not supposed that plants of this variety would prove resistant, as the Kelley variety does not do well when grown on diseased soil. As a matter of fact, a considerable number of plants of Station Kelley were just as resistant as the most resistant selections. Of 528 plants grown, 76, or 14 per cent, apparently were immune, 141 showed considerable resistance, while 311 showed no resistance (Figure 6). Evidently resistant strains have been isolated by the ordinary practis of selecting the best plants for seed during the 8 or 9 years this variety has been grown on the Station farm. Several of the fields on the Station farm are known

*The seed used in this planting was received from Mr. Charles Marvin, Midway, Kentucky, and planted by Mr. Leo Aswerus. Thru the co-operation of Mr. and Mrs. Aswerus, the seed of the selections was received by the Experiment Station.



Figure 6. Selection As. 10 (left) grown from seed of one of the 10 Vimont Kelley plants selected at Dry Ridge, Ky., in 1920. These plants were uniformly resistant. Center, a row planted from seed of Station Kelley obtained from several plants grown on disease-free soil the previous year. Several degrees of resistance are illustrated in the few plants shown. The value of obtaining seed from a single resistant mother plant is evident both because of resistance to root-rot and uniformity of type. Grown on diseased soil, 1921.

to be slightly infected with the root-rot organism and only the most vigorous plants have been saved for seed. A considerable number of selections were made from the 76 most resistant plants. These will be given further trial in 1922. In this field 5 strains known to be susceptible were grown and proved uniformly susceptible, indicating that the Station Kelley White Burley actually is a mixture of resistant, semi-resistant and susceptible strains and that the results obtained were not the result of chance.

CONCLUSION.

In conclusion it seems safe to state that we may expect to obtain strains of Standup White Burley tobacco immune to root-rot and of as high quality as the best strains contained in the commonly grown varieties. Already, resistant strains have been obtained having quality at least equal to that of the commonly grown varieties. In view of the prevalence of root-rot thruout the Burley section of Kentucky, we do not hesitate to recommend the use of these strains either on new land or on old land known to be diseased. On new land, as good results should be expected as can be obtained from the present varieties, with the added advantage of uniformity, making topping and grading easier. On diseased land or on land which has grown a single crop of tobacco, the value of the resistant strains is unquestioned.